

Induced Contamination Predictions for JAXA's MPAC&SEED Devices

Micro **P**article **C**apturer and **S**pace **E**nvironment **E**xposure **D**evice



Presented to
The International Symposium on
"SM/MPAC&SEED Experiment"
March 10-11, 2008

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Acknowledgement

The assistance of Naoko Baba and Kichiro Imagawa (JAXA) in obtaining MPAC&SEED contamination measurements is gratefully acknowledged.



Image courtesy of NASA



Introduction

SM/MPAC&SEED Experiment deployed
on the Service Module port-nadir side
(View from International Space Station Aft end)



Image courtesy of NASA

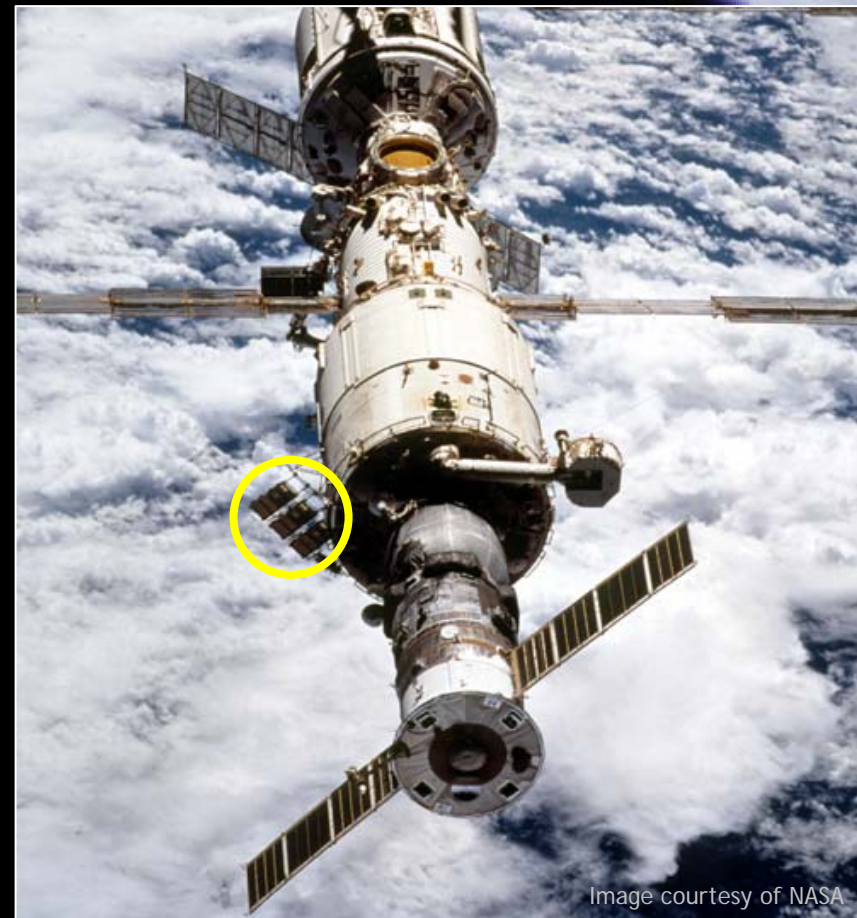


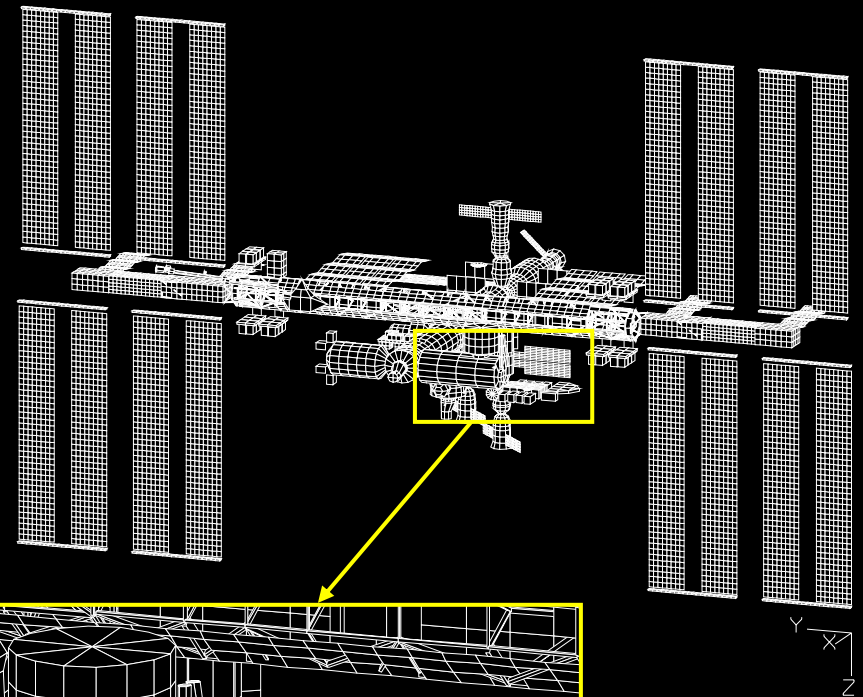
Image courtesy of NASA



Introduction

SM/MPAC&SEED Experiment deployed
on the Service Module port-nadir side
(View from International Space Station Aft end)

JEM/MPAC&SEED Experiment to be
deployed on Japanese Experiment
Module Payload Site
(Facing in RAM or +X Direction)



Approximate
JEM/MPAC&SEED
Location



Image courtesy of NASA



Background - SM/MPAC&SEED

- ➡ Three identical SM/MPAC&SEED units.
- ➡ Samples on the ram and wake facing surfaces.
 - MPAC - experiment to capture micrometeoroids and space debris particles.
 - SEED - exposure experiment to characterize degradation of materials in LEO.



A single MPAC&SEED Unit
(Ram-Facing Surface)

References:

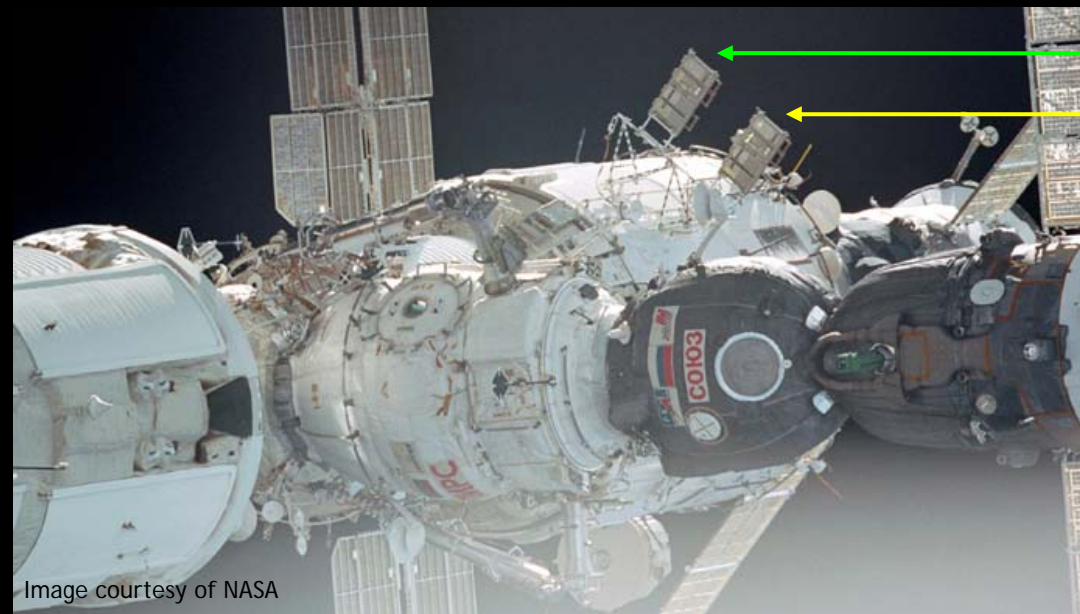
Neish, et. Al. *Microparticle Capture on the International Space Station Using Aerogel and Polyimide Foam*;
Imai, F. and Imagawa, K. *NASDA's Space Environment Exposure Experiment on ISS: First Retrieval of SM/MPAC&SEED.*

Image courtesy of NASA



Background - SM/MPAC&SEED

- ⇒ All 3 units deployed on October 15, 2001
- First unit retrieved on August 26, 2002 - *315 Days*
 - Second unit retrieved on February 26, 2004 - *865 Days*
 - Third unit retrieved on August 18, 2006 - *1403 Days*



Unit 3

Unit 2

MPAC&SEED with Unit 1 Removed
(Unit 2 was relocated into the position
previously occupied by Unit 1)

Image courtesy of NASA



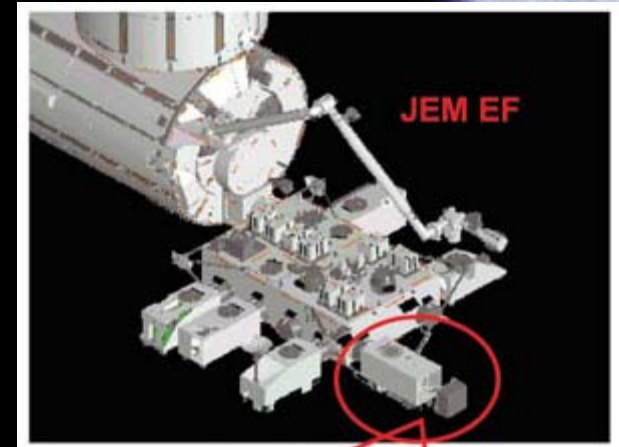
Background - JEM/MPAC&SEED

⇒ JEM/MPAC&SEED to be launched on ISS Flight 2J/A (ECD March 2009) with SEDA/AP External Payload

(SEDA/AP: Space Environment Data Acquisition equipment-Attached Payload)

⇒ Samples on the ram facing surface.

⇒ Planned exposure duration of 3 years.



SEDA-AP
(On orbit configuration)



JEM/MPAC&SEED



Reference:

JAXA. Space Environment Data Acquisition equipment-Attached Payload (Website), http://kibo.jaxa.jp/en/experiment/ef/seda_ap/, 15 Feb. 08.

Image courtesy of NASA



Contamination Sources

⇒ Possible contamination sources :

- Material outgassing-induced contamination
- Thruster plume-induced contamination
- Propellant purges
- Water vents
- Self-contamination

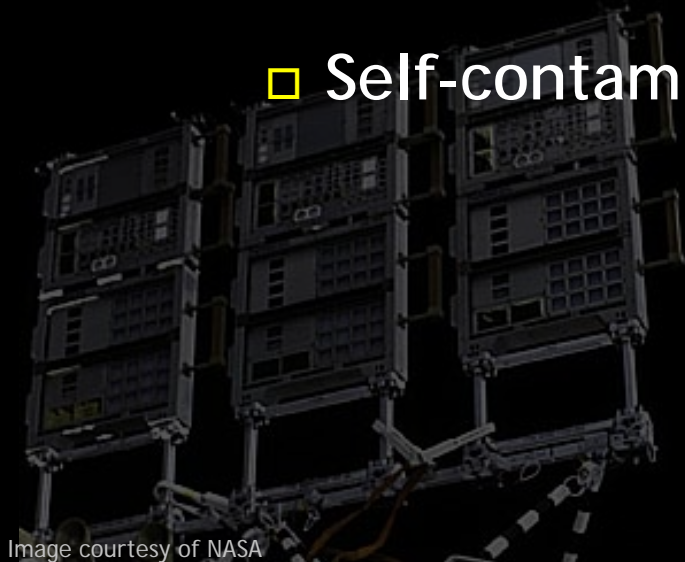


Image courtesy of NASA



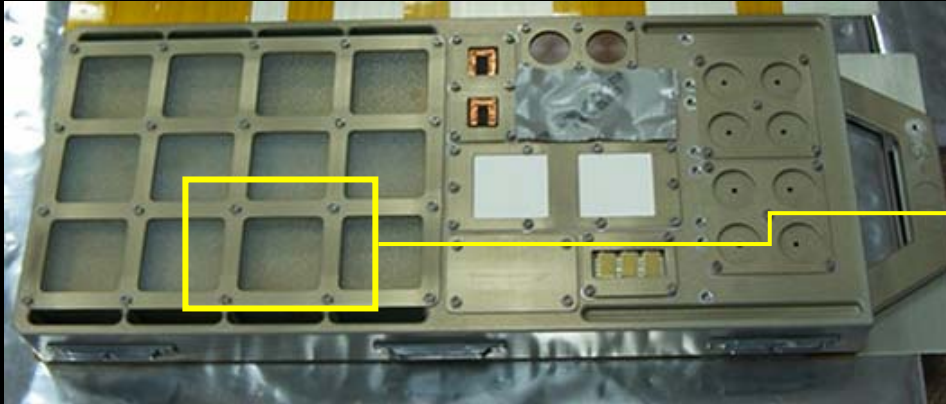
SM/MPAC&SEED

Induced Contamination Predictions and Measurements

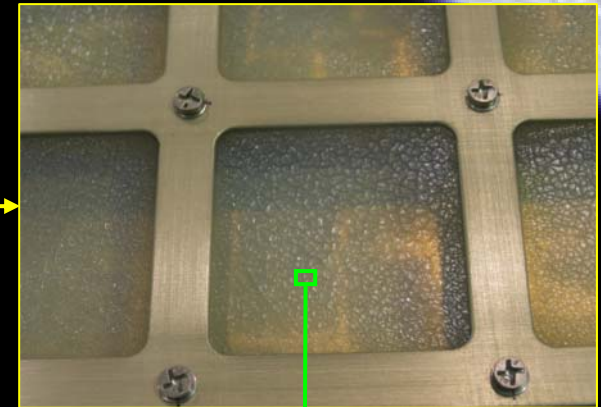


Image courtesy of NASA

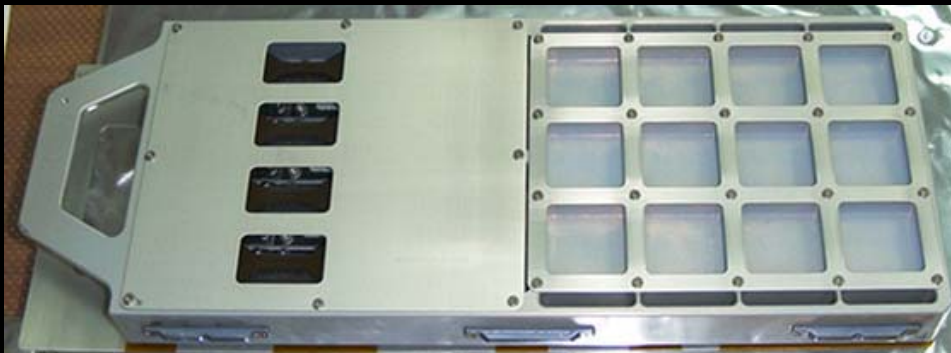
SM/MPAC&SEED Contamination Observations



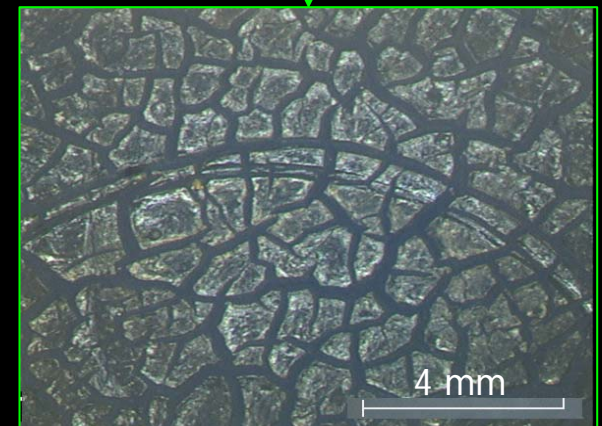
Wake face



Aerogel Sample



Ram face



Reference: Neish, Michael; Imagawa, Kichiro; Inoue, Toshihiko; Ishizawa, Junichiro; Kitazawa, Yukihiro; Yamaura, Yukiko; Murakami, Atsushi; Ochi, Yoshiyuki. *Microparticle Capture on the International Space Station Using Aerogel and Polyimide Foam.*



SM/MPAC&SEED XPS Measurements

⇒ X-ray Photoelectron Spectroscopy (XPS) used to measure element composition and depth profiles.

□ Element composition:

- Silicon major constituent on ram side. Also present on wake side in lesser quantities.
- Other constituents: oxygen, carbon, nitrogen, sodium, iron, and nickel.

□ Approximate Contamination Depth based on XPS Measurements:

Measured Contamination Depth - Angstroms (Å)			
Side	Unit 1	Unit 2	Unit 3
Ram (1)	300	750	930
Ram (2)	300	750	940
Wake (1)	55	100	110
Wake (2)	500	70	85

Reference: Baba, Naoko; Imagawa, Kichiro; Neish, Michael; and Inoue, Toshihiko. *External Contamination Control for JAXA Spacecraft*. ISTS 2004-h-06. Copyright 2004 by the Japan Society for Aeronautical and Space Sciences and ISTS.

Image courtesy of NASA



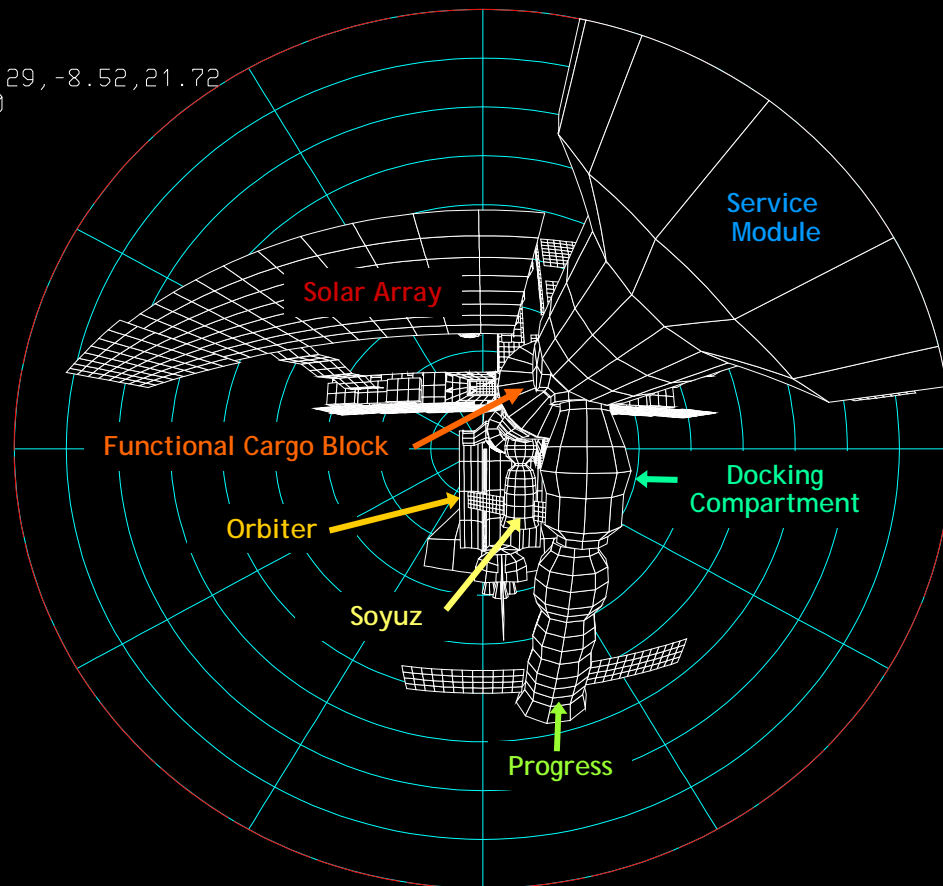
Contamination Sources

Material Outgassing

⇒ Hemispherical View from SM/MPAC&SEED Ram Side:

MPAC/SEED +x View

Location : -103.29,-8.52,21.72
Direction : 1,0,0





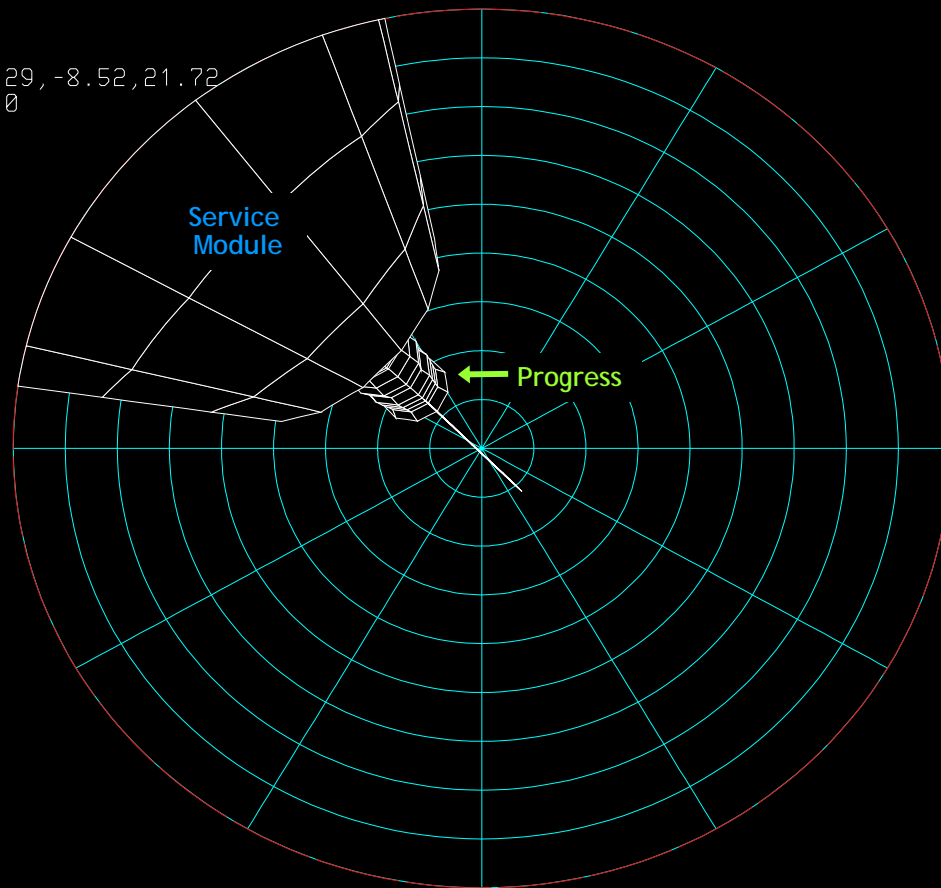
Contamination Sources

Material Outgassing

⇒ Hemispherical View from SM/MPAC&SEED Wake Side:

MPAC/SEED -x View

Location : -105.29,-8.52,21.72
Direction : -1,0,0





Contamination Sources

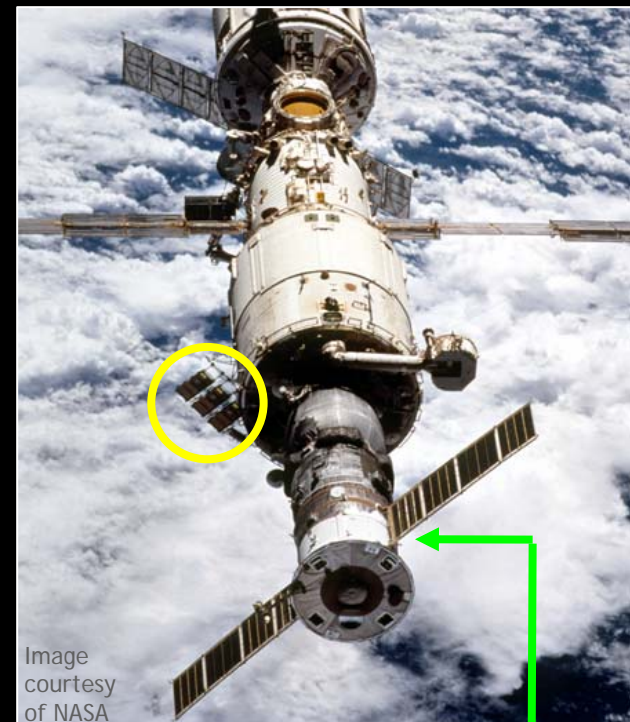
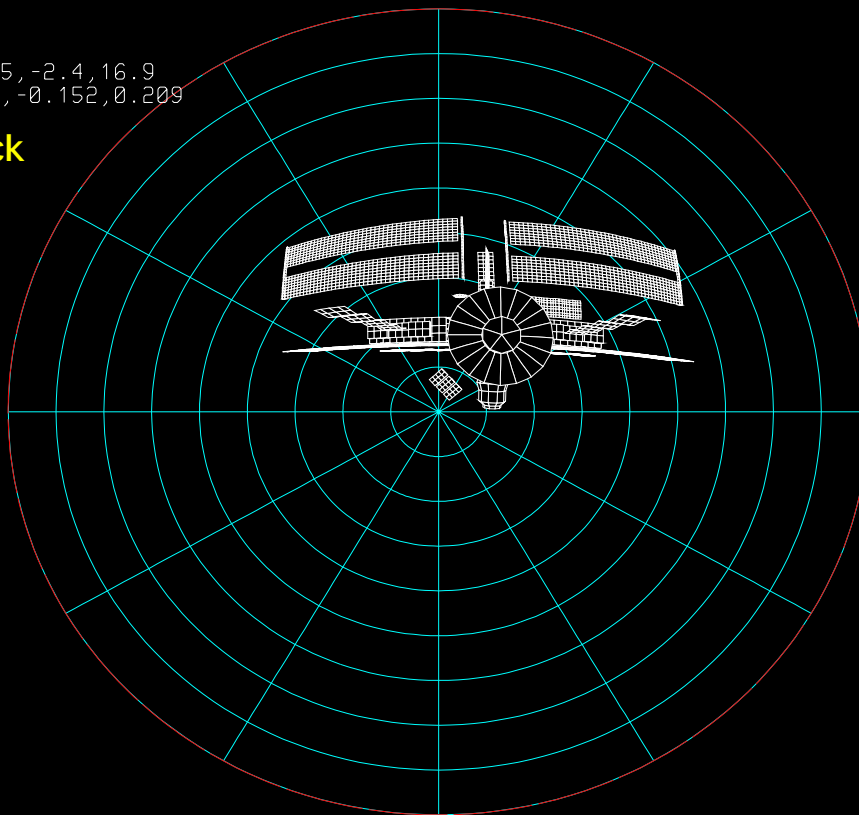
Thruster Plume

⇒ Hemispherical View to SM/MPAC&SEED wake side from Progress braking engines:

Progress PR14

Location : -150.5, -2.4, 16.9
Direction : 0.966, -0.152, 0.209

20 Feet to Dock



Progress docked
to aft end of ISS



Contamination Analysis

⇒ Materials Outgassing Analysis:

- Materials lists compiled for each ISS element.
 - Matched to available outgassing rate test data.
 - Other factors include temperature estimates, time decay scaling, and material quantity.
- Contamination calculated using an analytical model based on physical models of molecular transport.
 - Geometric model, view factor calculation, & transport routines also utilized in calculation.

⇒ Thruster plume contamination analysis:

- Available jet firing data used to simulate thruster firings.
- Contamination calculated with semi-empirical model based on flight experiment and chamber test data.

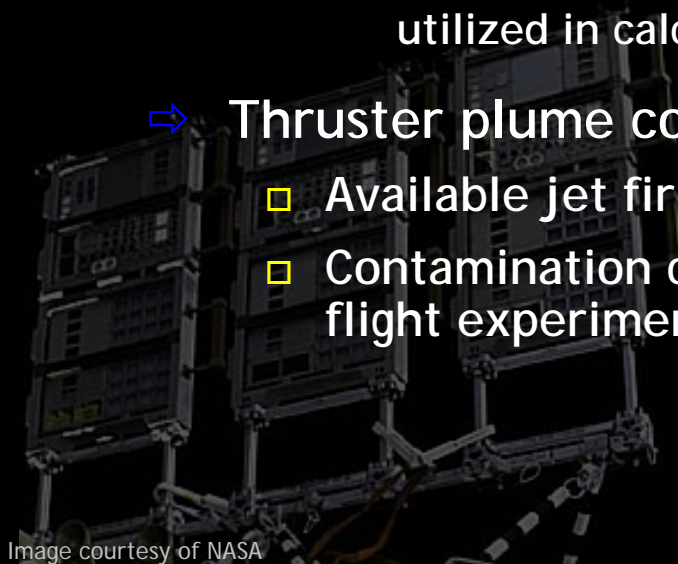


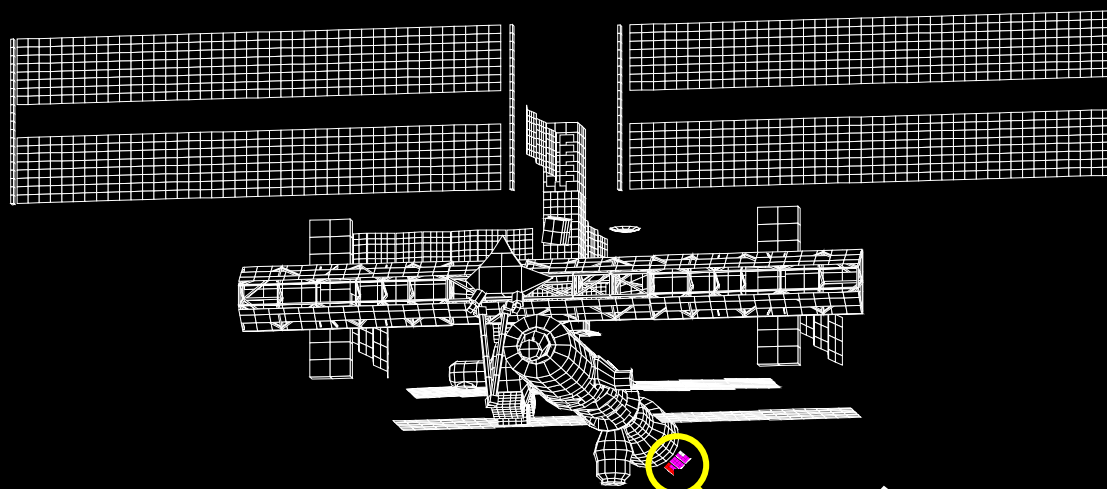
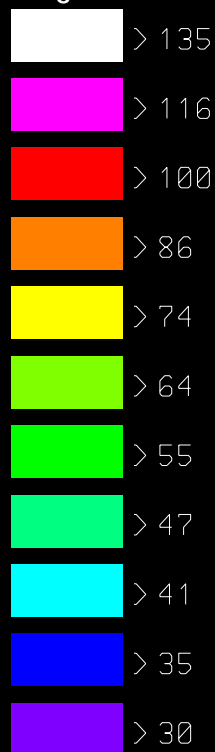
Image courtesy of NASA



Analysis Results

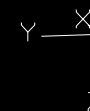
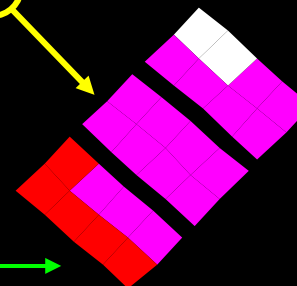
Example - SM/MPAC&SEED Unit 1 Ram Side (315 Days)

Angstroms



UNIT 1 - Ram Side
XPS Contamination Depth
Measurement 1 - 300 Å
Measurement 2 - 300 Å

Unit 1 →

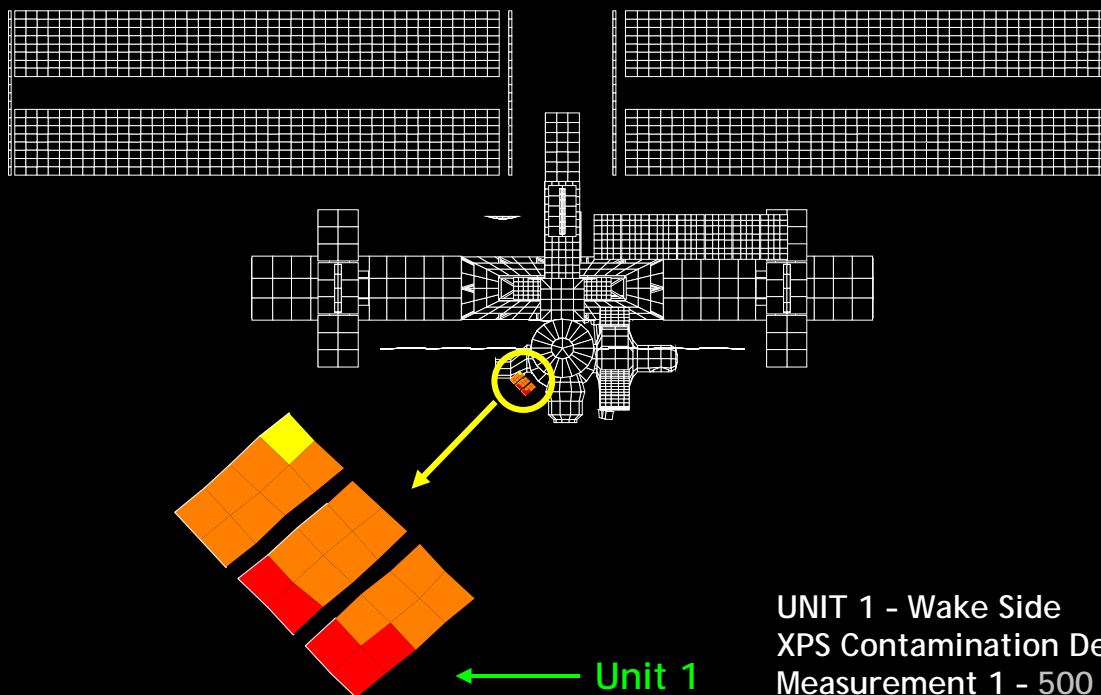




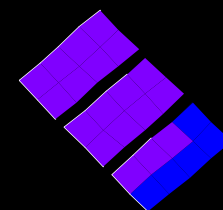
Analysis Results

Example - SM/MPAC&SEED Unit 1 Wake Side (315 Days)

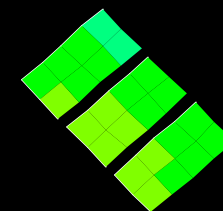
Angstroms



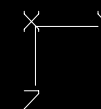
Contribution from
Material Outgassing



Contribution from
Thruster Plumes



UNIT 1 - Wake Side
XPS Contamination Depth
Measurement 1 - 500 Å
Measurement 2 - 50 Å





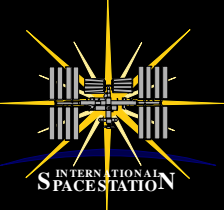
Analysis Summary

SM/MPAC&SEED

- ⇒ Results for Ram Side:
 - Material outgassing induced contamination predicted and measured.
- ⇒ Results for Wake Side:
 - Contamination predicted from combination of materials outgassing and thruster plume impingement.
- ⇒ Calculated depth of contamination within a factor of 2-3 of measured contamination.

Measured Vs. Predicted Contamination Depth (Å)						
Side	Unit 1		Unit 2		Unit 3	
	Measured	Predicted	Measured	Predicted	Measured	Predicted
Ram	300	106 - 135	750	303 - 354	930	459 - 533
Ram	300		750		940	
Wake	55	86 - 103	100	186 - 237	110	317 - 414
Wake	500		70		85	

Image courtesy of NASA



Measurements Vs. Predictions

- ⇒ Results are qualitatively consistent with XPS measurements.
 - On ram side, predictions and measurements dominated by a silicon-based contaminant.
 - Lesser degree of silicon-based contaminant predicted and measured on wake side.
 - Droplet features and presence of Nitrogen on wake side are indicative of thruster plume induced contamination.
- ⇒ Predicted results for Ram Side show good agreement with XPS measurements.
 - Possible improvements for material outgassing calculation:
 - Better characterization of the outgassing sources.
 - Additional consideration for on-orbit thermal environment.
- ⇒ XPS measurements have limitations in regard to quantifying plume contamination.
 - Thruster plumes have multiple byproducts.
 - Dominated by the liquid phase, producing droplet features and a less uniform contamination layer.

Image courtesy of NASA



JEM/MPAC&SEED

Induced Contamination Predictions



Image courtesy of NASA



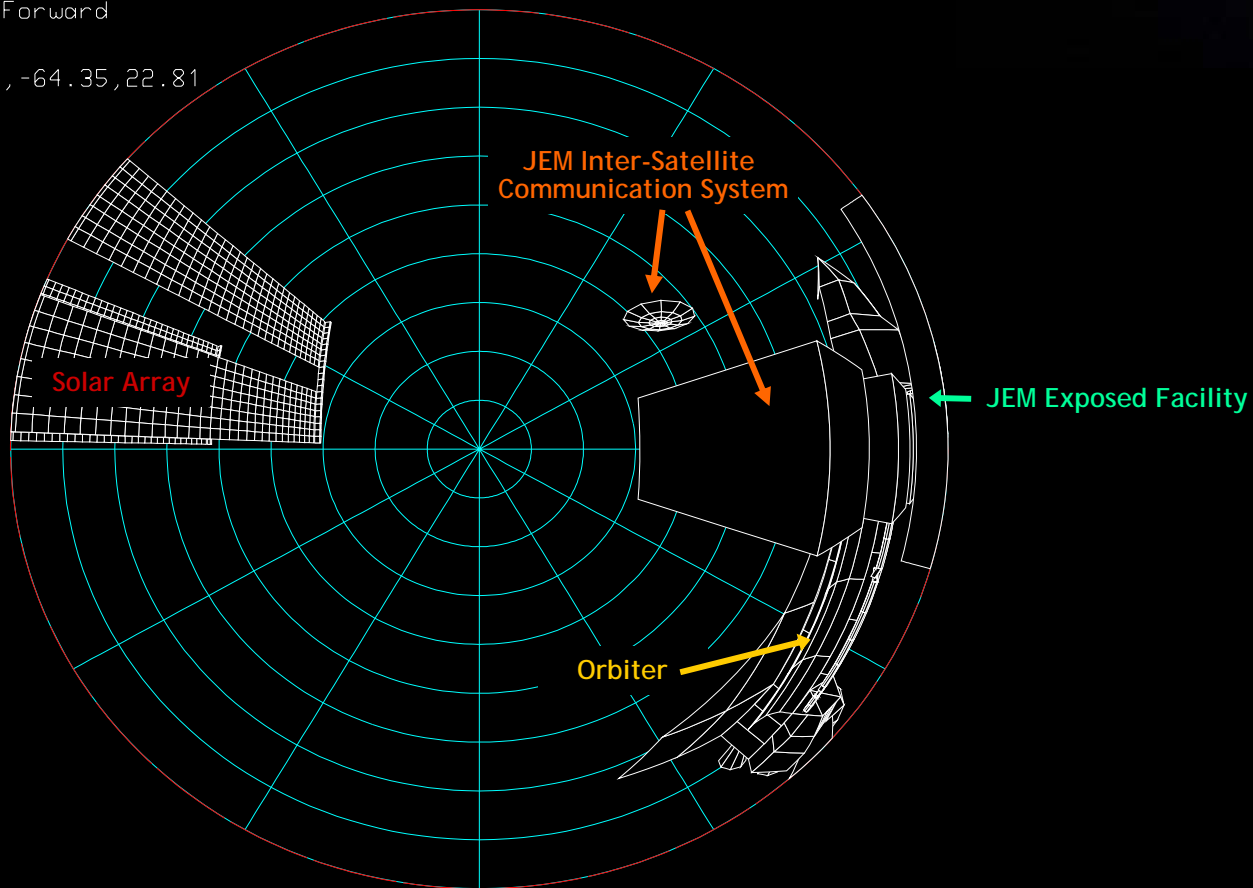
Contamination Sources

Material Outgassing

⇒ Hemispherical View from JEM/MPAC&SEED:

View from SEDA-AP Forward

Location : 44.08, -64.35, 22.81
Direction : 1,0,0





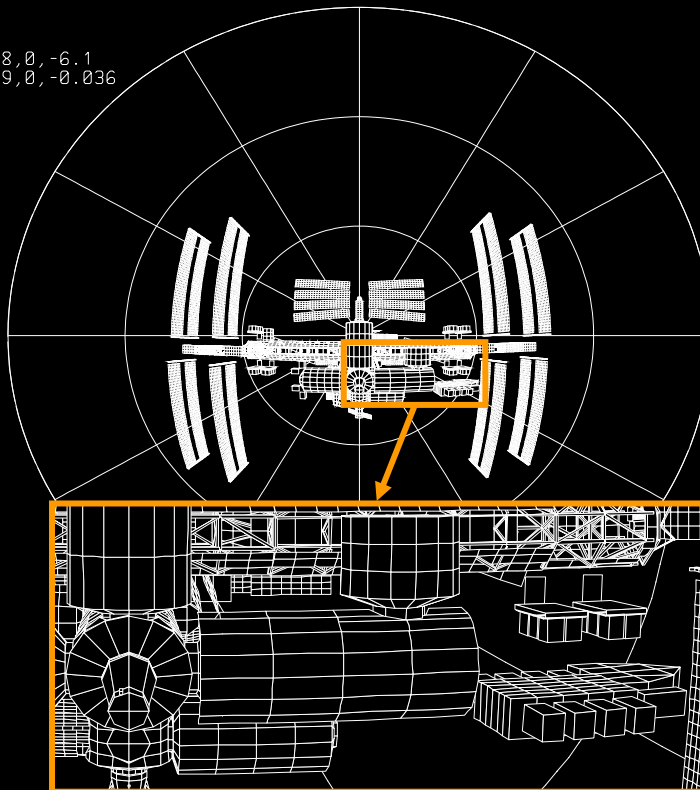
Contamination Sources

Thruster Plume

⇒ Hemispherical View to JEM/MPAC&SEED from select Orbiter thrusters:

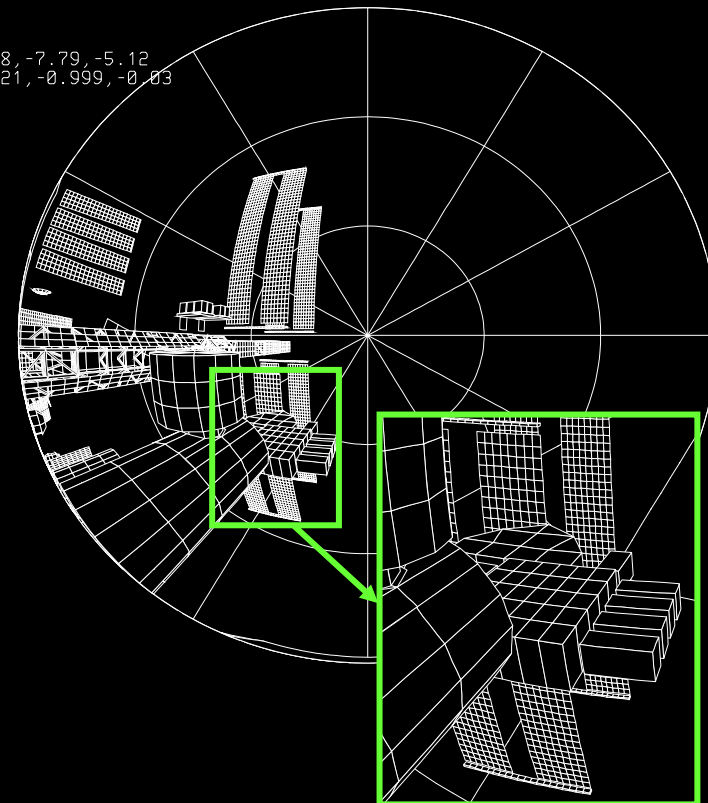
Orbiter Braking Thruster, Range = 100ft

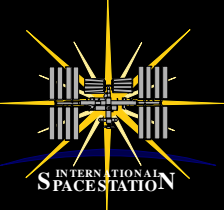
Location : 158.38,0,-6.1
Direction : -0.999,0,-0.036



Orbiter Side Firing Thruster, Mated

Location : 61.78,-7.79,-5.12
Direction : -0.021,-0.999,-0.03





Analysis Results

JEM/MPAC&SEED

- ⇒ Material outgassing is the primary source of induced contamination predicted.
 - Depth of contamination layer dependent on JEM/MPAC&SEED surface temperature.
 - Majority of outgassing contamination comes from JEM hardware due to close proximity and view factor.
- ⇒ Orbiter thruster plume induced contamination predicted to be negligible.

**Predicted Contamination Depth (Å) due to Material Outgassing Sources
(for 3 year exposure duration)**

JEM/MPAC&SEED Temperature	JEM (EF and ICS)	ISS (Solar Array & Orbiter)	Total
-40°C	258.7 Å	3.3 Å	262 Å
-10°C	100.2 Å	3.3 Å	103 Å
25°C	41.5 Å	2.9 Å	44 Å

Image courtesy of NASA



Conclusions

- ⇒ Externally mounted ISS payloads are exposed to the induced ISS environment, including material outgassing and thruster plume contamination
- ⇒ The Boeing Space Environments Team developed analytical and semi-empirical models to predict material outgassing and thruster plume induced contamination.
- ⇒ JAXA's SM/MPAC&SEED experiment provides an unique opportunity to compare induced contamination predications with measurements.
 - Analysis results are qualitatively consistent with XPS measurements.
 - Calculated depth of contamination within a factor of 2-3 of measured contamination.
 - Represents extremely good agreement, especially considering long duration of experiment and number of outgassing sources.
 - Despite XPS limitations in quantifying plume contamination, the measured and predicted results are of similar scale for the wake-facing surfaces.
- ⇒ JAXA's JEM/MPAC&SEED experiment will also be exposed to induced contamination due to JEM and ISS hardware.
 - Predicted material outgassing induced contamination to JEM/MPAC&SEED ranges from 44Å to 262Å (depending on surface temperature) for a 3 year exposure duration.

Image courtesy of NASA